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Applicability of Four Regional Volume Tables for Estimating Growth Response to Thinning in Douglas-Fir

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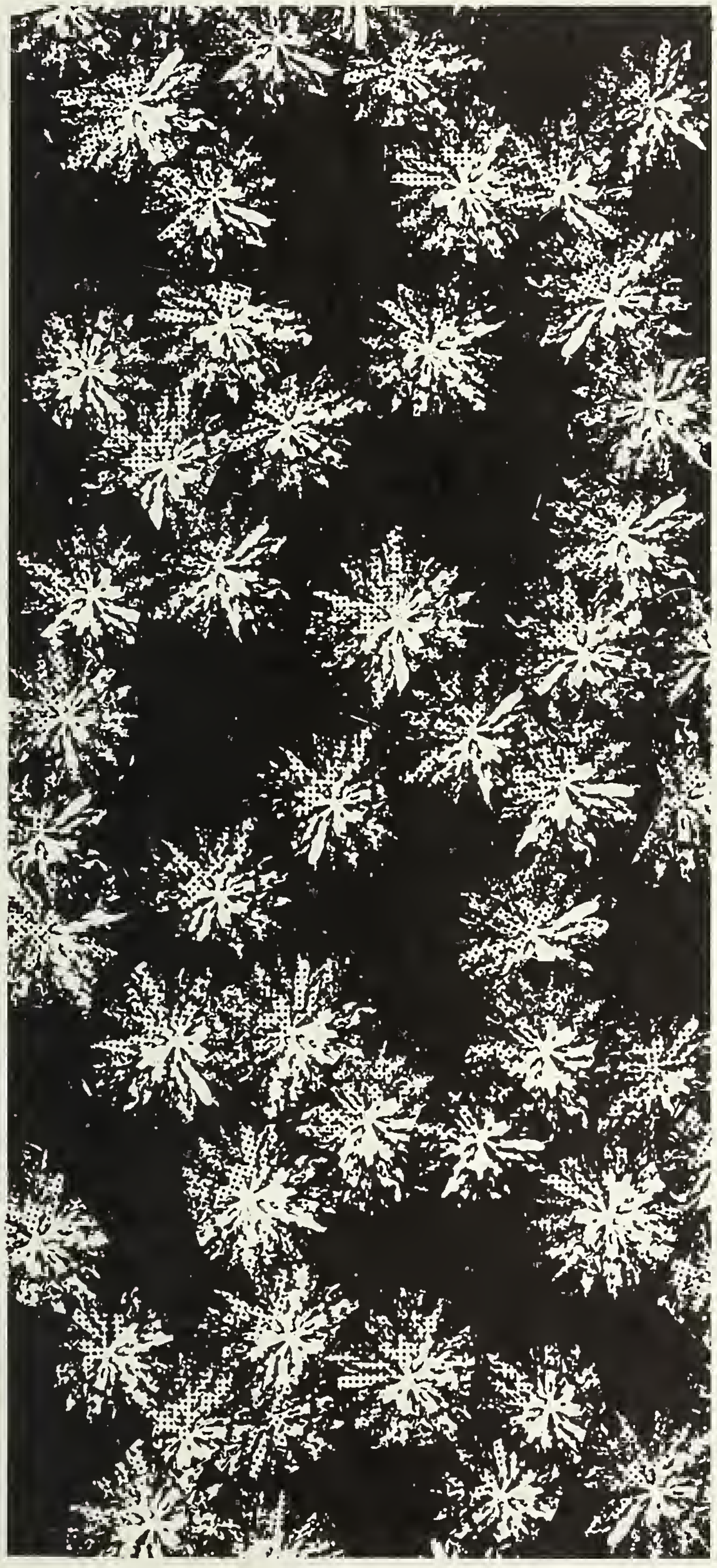

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Abstract

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Similar estimates of tree and stand growth 19 years after thinning a 110-year-old stand of Douglas-fir were derived from stem analysis and standard volume-table, plot-compilation procedures.

Keywords: Volume tables, thinnings (-stand volume, stem analysis, Douglas-fir, *Pseudotsuga menziesii*.

Summary

Regional, two-entry (d.b.h. and height) volume tables are routinely used to estimate the volume and volume growth of trees and stands, because alternatives—such as stem analysis or complete stem measurement—are prohibitively expensive or in conflict with study objectives. Thinning could conceivably affect the difference between actual volume and volume growth and estimates of volume and volume growth derived from volume tables. Such an effect could cause misleading inferences about results of thinning experiments.

The size and direction of such differences were tested 19 years after a 110-year-old stand of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) was thinned. Sections of stems were taken from 72 trees—sampling control, light, and heavy thinnings and dominant, codominant, intermediate, and suppressed crown classes—to analyze volume growth for 19 years before and 19 years after thinning. Estimates of volume growth for the same stands were also made from four volume equations (tables) and the results compared.

Thinning had no significant effect on the differences. Estimates of stand growth from volume tables agree with the stem analysis within about 10 percent, with standard errors of means ($p \leq 0.10$) 5 percent or less.

Introduction

Forest researchers commonly use regional volume equations (tables) to estimate volume of trees or stands and to compare growth response to various cultural treatments. Typically, these equations require only tree d.b.h. and total height. Four such regional volume equations are used in the Pacific Northwest for coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*).

To determine whether silvicultural treatments influence local differences[1] between actual volumes and volume-table estimates, we measured by stem analysis the volume and volume growth of individual trees in two, long-term growth studies and compared the results with the corresponding estimates from each of the four standard volume equations. Because the results were from, and should be applied to, older stands or young stands thinned lightly, results should not be extrapolated too far, especially to younger stands with wide ranges of stocking level control.

[1] The term difference or discrepancy is used because calculated values in this study include both bias and random variations.

Methods

The Study Area

Boundary Creek.—The primary stand studied was at Boundary Creek, in the Wind River Experimental Forest, near Carson, Washington. The stand was first thinned in 1952 at age 110 years, when an experiment consisting of three replications each of heavy thinning, light thinning, and control was established. The free-thinning method used has been described by Braathe (1957). Heavy thinning reduced cubic volume to an average of 62 percent of normal (McArdle et al. 1961) by removing 26 percent of initial volume. Light thinning reduced cubic volume to an average 78 percent of normal by removing 19 percent of initial volume. Stocking before thinning averaged 87 percent of normal cubic volume (Williamson 1966). A second thinning was made in 1971.

Snow Creek.—Supplementary data were available from three plots in the Snow Creek plantation, established in 1926 at an initial spacing of 8 x 8 feet, in Olympic National Forest near Quilcene, Washington. Two half-acre plots were first thinned at age 26, and were rethinned at ages 31, 36, 42, and 48. One half-acre plot was an unthinned control (Worthington 1961).

The first two thinnings were light, removing about 12 and 17 percent of initial volume. Later thinnings removed from 16 to 32 percent of volume.

Data Collection

Stem analyses were made from felled trees at the most recent thinnings on both areas. Trees were selected to sample the range of available diameters, prethinning competition, and release.

At Boundary Creek, two trees were selected on each plot from each of the dominant, codominant, intermediate, and suppressed crown classes, for a total of 72 trees over the nine plots.

The sample at Snow Creek was much smaller, including only 10 trees from the thinned plots and six trees from the unthinned area adjacent to the control plot, all unsegregated by crown class.

Discs were cut from each tree at stump height, breast height, base of live crown, and at 10, 30, 50, 70, and 90 percent of total 1952 height—a technique similar to Altherr's (1960).

Diameter (D) of each disc (inside bark) was calculated as twice the quadratic mean of eight regularly spaced radii (r), with initial radius randomly oriented. That is:

$$D = 2\,\{\Sigma r_i^2/8\}^{1/2}$$

Tree volume was calculated as the sum of the volumes of truncated right circular cones for sections above the stump, plus stump volume calculated as a cylinder.

Table 1 presents average values by crown classes and thinning treatments for Boundary Creek, at the time of first thinning (age 110), of d.b.h., total height, and cubic volume calculated from stem analyses.

For the limited Snow Creek data, at time of first thinning (age 26), sampled trees ranged from 6.7 to 8.8 inches in d.b.h. and from 5.2 to 10.2 cubic feet in volume. By age 48, the range was 10.1 to 15.5 inches in d.b.h., and 20.5 to 57.6 cubic feet in volume.

For Boundary Creek, tree dimensions and volumes were estimated as of 19 years before thinning (age 91); time of thinning (age 110); and 19 years after thinning (age 129).

For Snow Creek, tree dimensions and volumes were estimated as of age 26 (first thinning); age 36 (third thinning); and age 48 (fifth thinning).

The tree diameters and heights determined by stem analyses at each of these stand ages were then used to calculate estimated cubic foot volumes by the volume equations given by Browne (1962), Bruce and DeMars (1974), Curtis (1966), and Turnbull and King.[2]

Analysis

My primary interest was in possible treatment-related differences between measured and estimated volumes, and in their consistency or possible trends over time. Any regional volume equation can be expected to show volume discrepancies for any one stand. But such discrepancies would lead to misinterpretation of results of experimental treatments and to serious errors in growth estimates only if they are associated with the treatment and change substantially over the period of observation.

I first tested volume discrepancies (transformed by multiplying by the reciprocal of equation estimates to equalize variances); that is,

$$\frac{\text{(stem-analysis volume) - (equation estimate)}}{\text{(equation estimate)}},$$

to see if significant differences existed among thinning treatments, crown classes (Boundary Creek only), and years.

[2] Turnbull, K.J., and J.E. King. Weyerhaeuser Company, Forestry Research Laboratory, Centralia, Washington. $\text{Log } V = 3.21809 + 0.04948 (\log H)(\log D) - 0.15664 (\log D)^2 + 2.02132 (\log D) + 1.63408 (\log H) - 0.16185 (\log H)^2$.

Table 1—Average dimensions of the six trees in each thinning treatment and crown class at the first thinning (age 110), Boundary Creek

Crown class	Control			Light			Heavy		
	Diameter	Height	Volume	Diameter	Height	Volume	Diameter	Height	Volume
	Inches	*Feet*	*Cubic feet*	*Inches*	*Feet*	*Cubic feet*	*Inches*	*Feet*	*Cubic feet*
Dominant	24.5	144	172	25.7	152	169	20.8	125	104
Codominant	18.5	130	92.7	22.8	138	114	17.6	121	77.9
Intermediate	17.0	131	84.7	17.3	122	74.9	15.3	107	55.2
Suppressed	12.4	106	34.7	14.4	108	42.9	12.3	93	30.0

At Boundary Creek, data for the two trees in a plot/crown-class cell were averaged, and the averages entered as observations in analyses of variance. Analyses followed a split-plot design using the original randomized-block design of the Boundary Creek thinning experiment, with years as subplots.

The Snow Creek analysis was treated as a simple split-plot design with individual trees as sources of observation.

A separate analysis was done for each area and for each volume equation. For Boundary Creek, the analysis of variance table is as follows:

Source of Variation	**Degrees of freedom**
Replications	2
Thinning treatment (T)	2
Error for testing major plot treatments	4
Crown class (CC)	3
TXCC	6
Error for testing intermediate plot classes	18
Year (Y)	2
TXY	4
CCXY	6
TXCCXY	12
Error for testing minor plot classes	48
Total	107

I then made a similar split-plot analysis of relative differences in volume growth, expressed as

$$\frac{(\Delta \text{ stem analysis volume}) - (\Delta \text{ equation estimate})}{(\Delta \text{ equation estimate})},$$

where Δ indicates the difference between volume at start and volume at end of the measurement period. In all statistical tests, differences between treatments or classes were deemed significant if $p \leq .10$.

Results

Boundary Creek

Volume discrepancies.—Averages of volume differences for the six trees in each thinning-treatment/crown-class cell, in cubic feet and in percent, are presented in tables 2a and 2b by equation, thinning treatment, year, and crown class.

Significant differences are indicated among years for the Turnbull-King and Curtis equations (table 3). The thinning x year interaction was significant for all equations. No effect of thinning alone was discernible when volume discrepancies were averaged over crown classes and years.

Percentage deviations differed significantly by crown class for three of the four equations, with the discrepancies generally tending from positive to negative for dominant through suppressed crown classes. The largest discrepancies are for codominant trees in lightly thinned plots; they are associated with four of the six trees in the cell, which had above average taper in the lower 1/10 of the bole, evidently not accounted for by the double-entry volume equations used.

Table 2A—Average volume discrepancy for the six trees in each thinning treatment and crown class, by year and by volume equation, with volume by stem analysis illustrated, Boundary Creek

Crown Class	Tree Volume			Discrepancy											
				Bruce-DeMars			Turnbull-King			Curtis			Browne		
	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy
	Cubic feet														
	1933														
Dominant	131.41	131.46	83.71	-2.71	-.60	-1.62	-1.49	1.99	-.72	5.54	6.94	1.60	.96	4.77	2.78
Codominant	74.98	90.73	61.77	-1.79	-10.54	1.47	-.71	-9.08	2.01	1.28	-5.95	3.00	1.85	-5.77	4.78
Intermediate	63.21	62.77	44.80	-.48	-1.07	-.80	.44	-.16	-.71	1.81	.93	-.10	2.70	2.23	1.75
Suppressed	29.94	36.47	25.39	-1.52	-1.92	-.82	-1.62	-1.92	-.99	-1.13	-1.40	-.94	-.04	.14	.52
24-tree average	74.89	80.36	53.92	-1.62	-3.53	-.44	-.84	-2.29	-.10	1.87	.13	.89	1.37	.34	2.46
	1952														
Dominant	172.21	169.09	103.67	.51	-.30	-2.51	2.55	3.75	-.79	11.60	9.92	2.47	3.16	4.70	2.38
Codominant	92.76	113.71	77.92	-2.42	-11.59	.50	-.51	-9.10	1.75	2.04	-5.15	3.27	2.14	-6.46	4.50
Intermediate	84.44	74.88	55.16	-.31	.61	-.59	1.62	2.00	-.13	3.14	3.11	.91	3.58	4.31	2.43
Suppressed	34.66	42.90	30.29	-2.72	-2.39	-1.10	-2.69	-2.19	-1.20	-1.89	-1.34	-.95	-.98	-.02	.52
24-tree average	96.02	100.14	66.76	-1.24	-3.42	-.93	.24	-1.39	-.09	3.72	1.63	1.42	1.98	.63	2.46
	1971														
Dominant	204.67	206.57	123.61	2.35	4.89	-2.79	4.45	9.80	-.31	15.20	16.89	3.74	3.02	8.71	2.37
Codominant	109.24	135.58	95.04	-3.35	-10.18	-1.11	-.62	-7.20	1.03	2.28	-2.15	2.67	1.61	-5.14	3.47
Intermediate	103.33	84.96	64.82	-1.38	1.19	-.70	1.56	3.01	.07	2.95	4.21	1.43	3.00	5.26	2.79
Suppressed	37.86	48.77	36.11	-3.26	-4.31	-1.32	-3.12	-2.88	-1.33	-2.32	-1.85	-.94	-1.34	-.59	.67
24-tree average	113.77	118.97	79.89	-1.41	-2.10	-1.48	.57	.69	-.14	4.53	4.27	1.73	1.57	2.06	2.32

Table 2B—Average volume-equation discrepancy for the six trees in each thinning treatment and crown class, with volume by stem analysis Illustrated, Boundary Creek (each discrepancy is a percentage of its respective equation estimate)

	Tree Volume			Discrepancy											
				Bruce-DeMars			Turnbull-King			Curtis			Browne		
Crown Class	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy
	Cubic feet			Percent											
							1933								
Dominant	131.41	131.46	83.71	-2.02	- .45	-1.90	-1.12	1.54	- .85	4.40	5.58	1.94	.73	3.76	3.44
Codominant	74.98	90.73	61.77	-2.33	-10.41	2.44	- .93	-9.09	3.36	1.74	-6.16	5.11	2.53	-5.98	8.39
Intermediate	63.21	62.77	44.80	- .75	- 1.67	-1.75	.71	- .25	-1.55	2.94	1.50	- .22	4.46	3.68	4.06
Suppressed	29.94	36.47	25.39	-4.82	- 4.99	-3.12	-5.12	-5.01	-3.77	- 3.63	-3.70	-3.58	- .12	.37	2.09
24-tree average	74.89	80.36	53.92	-2.48	- 4.38	-1.08	-1.97	-3.20	- .70	1.36	.70	.81	1.90	.46	4.50
							1952								
Dominant	172.21	169.09	103.67	.29	- .17	-2.37	1.50	2.26	- .76	7.22	6.23	2.44	1.87	2.86	2.35
Codominant	92.76	113.71	77.92	-2.55	- 9.25	.64	- .55	-7.41	2.30	2.25	-4.33	4.38	2.36	-5.38	6.13
Intermediate	84.44	74.88	55.16	- .37	.82	-1.05	1.96	2.74	- .24	3.86	4.33	1.67	4.43	6.10	4.61
Suppressed	34.66	42.90	30.29	-7.29	- 5.27	-3.49	-7.19	-4.85	-3.82	- 5.18	-3.03	-3.05	-2.74	- .05	1.75
24-tree average	96.02	100.14	66.76	-2.48	-3.46	-1.57	-1.07	-1.82	- .63	2.04	.80	1.36	1.48	.88	3.71
							1971								
Dominant	204.67	206.57	123.61	1.16	2.43	-2.20	2.22	4.98	- .25	8.02	8.90	3.12	1.50	4.40	1.95
Codominant	109.24	135.58	95.04	-2.97	- 6.98	-1.16	- .56	-5.04	1.10	2.13	-1.56	2.89	1.49	-3.65	3.79
Intermediate	103.33	84.96	64.82	-1.31	1.42	-1.06	1.53	3.67	.10	2.94	5.22	2.25	2.99	6.60	4.50
Suppressed	37.86	48.77	36.11	-7.92	- 8.11	-3.53	-7.61	-5.57	-3.55	- 5.77	-3.66	-2.53	-3.43	-1.20	1.88
24-tree average	113.77	118.97	79.89	-2.76	- 2.81	-1.99	-1.10	- .49	- .65	1.83	2.22	1.43	.64	1.54	3.03

Table 3—Significance levels of the F tests in the analyses of variance of relative differences in volume obtained by stem analysis and equation estimates

Factor	Equation			
	Bruce-DeMars	Turnbull-King	Curtis	Browne
Thinning (T)	0.760	0.891	0.858	0.747
Crown class (CC)	.049	.019	.005	.137
TXCC	.375	.426	.598	.381
Year (Y)	.938	.040	.004	.123
YXT	.052	.017	.101	.020
YXCC	.015	.028	.227	.267
YXTXCC	.092	.300	.346	.177

Most of the average deviations of volumes estimated by equation from those derived by stem analysis (tables 2a and 2b), whether by crown class or thinning treatment, are small. Even those differences that are statistically significant could easily have arisen from the techniques of stem analysis or volume computation rather than from the effects of thinning or inadequacy of the volume equations. They probably are of no practical magnitude.

Most of the discrepancies for the Bruce-DeMars and Turnbull-King equations are negative; most for the Curtis and Browne equations are positive. Mean deviations by year and thinning treatment (24 trees), however, do not exceed 5 percent for any of the equations.

Volume-growth discrepancies.—For all volume equations, thinning treatment had no significant effect on volume-growth discrepancies, nor was the thinning x period interaction significant, despite the significant year x thinning interaction found for volume estimates. The pattern of these nonsignificant differences among treatments is quite similar for the periods before and after thinning (fig. 1). This suggests that if the differences are real, they probably are not a result of thinning. This result is consistent with the generally small deviations of volume estimates from stem-analysis volumes (table 2).

Volume-growth discrepancies for the treatment averages of 24 trees—which correspond roughly to what one would expect from stand summaries—are all less than 10 percent (fig. 1 and table 4), and standard errors of the means ($p \leq 0.10$) are all 5 percent or less.

Figure 1.—Discrepancy of volume growth (24-tree averages) as percent of growth estimated by table—(measured - estimated) /estimated—by period, volume equation, thinning treatment, and d.b.h. class, Boundary Creek.

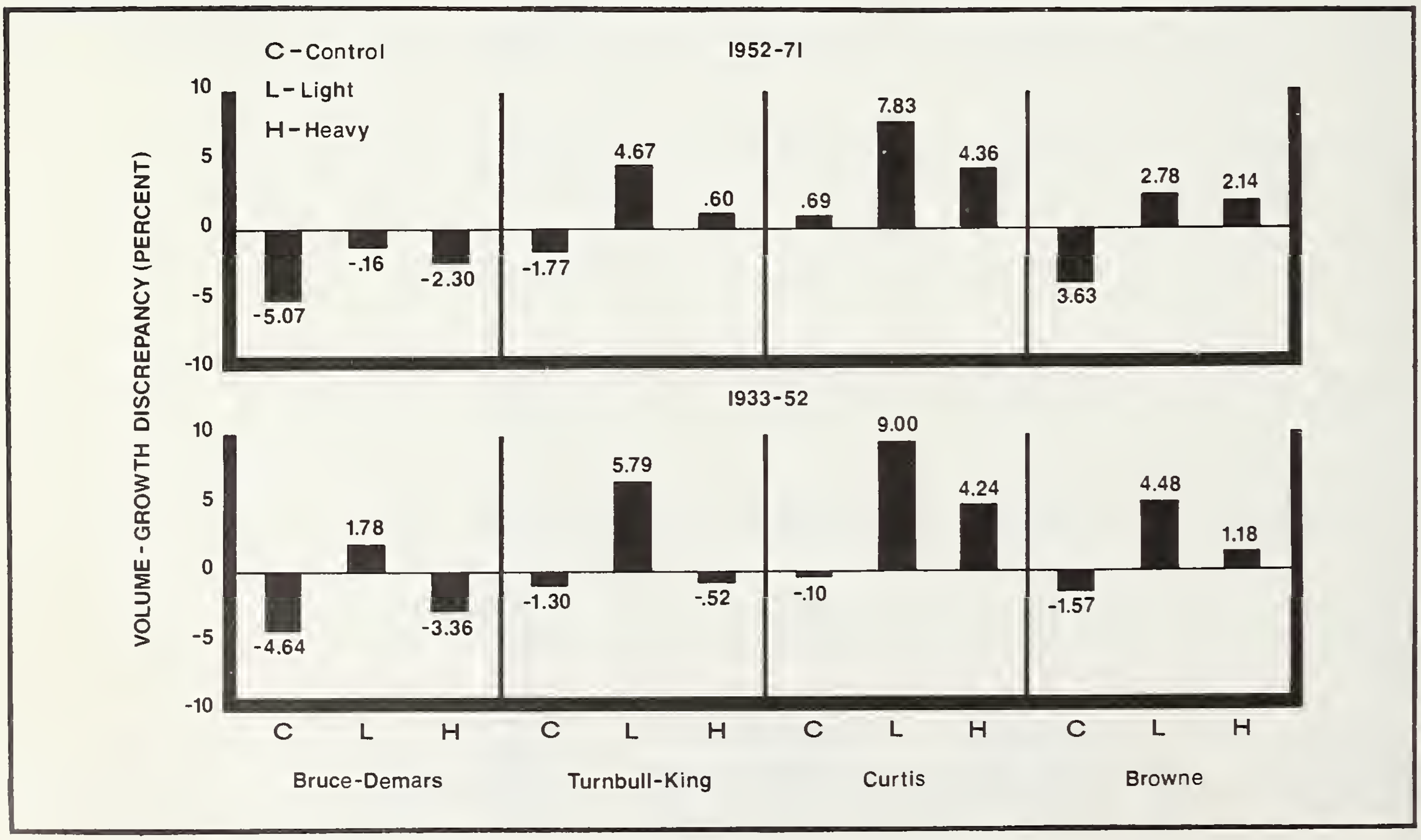

Table 4A—Average volume-growth discrepancy for the six trees in each thinning treatment and crown class, by period and by volume equation, Boundary Creek

Crown Class	Volume growth by stem analysis			Discrepancy											
				Bruce-DeMars			Turnbull-King			Curtis			Browne		
	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy
							Cubic feet								
							1933-52								
Dominant	40.80	37.63	19.96	3.21	.30	- .90	4.04	1.76	- .08	6.07	2.98	.87	2.20	- .06	- .40
Codominant	17.78	22.97	16.15	- .64	-1.05	- .98	.19	- .03	- .26	.76	.80	.27	.29	- .69	- .28
Intermediate	21.23	12.11	10.36	.17	1.68	.21	1.18	2.16	.58	1.33	2.18	1.01	.89	2.08	.68
Suppressed	4.72	6.43	4.91	-1.21	- .47	- .28	-1.07	- .26	- .21	- .77	.06	- .01	- .94	- .16	.00
24-tree average	21.13	19.79	12.84	.38	.11	- .48	1.08	.91	.01	1.85	1.51	.53	.61	.29	.00
							1953-71								
Dominant	32.46	37.47	19.94	1.85	5.19	- .27	1.90	6.06	.48	3.59	6.97	1.28	- .14	4.01	- .02
Codominant	16.47	21.88	17.12	- .92	1.42	-1.61	- .11	1.91	- .72	.24	3.00	- .60	- .54	1.32	-1.03
Intermediate	18.89	10.09	9.66	-1.07	.58	- .11	- .06	1.01	.20	- .19	1.11	.52	.58	.95	.36
Suppressed	3.21	5.87	5.82	- .53	-1.92	- .23	- .43	- .69	- .13	- .43	- .51	.02	- .37	- .57	.15
24-tree average	17.76	18.83	13.13	- .17	1.32	- .55	.33	2.07	- .04	.81	2.64	.30	- .41	1.43	- .13

Table 4B—Average volume-growth discrepancy as a percent of the tabular estimate for the six trees in each thinning treatment and crown class relative to growth estimated by volume equations, by period and volume equations, Boundary Creek

Crown Class	Volume growth by stem analysis			Discrepancy											
				Bruce-DeMars			Turnbull-King			Curtis			Browne		
	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy	Control	Light	Heavy
	Cubic feet			Percent											
1933-52															
Dominant	40.80	37.63	19.96	6.69	.90	-1.12	9.48	5.35	2.34	15.87	8.45	8.34	5.26	.57	2.07
Codominant	17.78	22.97	16.15	- 3.86	- 2.47	-7.00	.51	1.69	-3.34	4.17	5.54	.52	1.99	- 1.14	-2.66
Intermediate	21.23	12.11	10.36	- 1.56	12.14	2.35	2.83	16.83	5.51	4.22	17.65	10.46	2.49	17.14	7.83
Suppressed	4.72	6.43	4.91	-19.84	- 3.47	-7.68	-18.00	- .72	-6.58	-13.23	4.35	- 2.36	-16.03	1.35	-2.51
24-tree average	21.13	19.79	12.84	- 4.64	1.78	-3.36	- 1.30	5.79	- .52	2.76	9.00	4.24	- 1.57	4.48	1.18
1953-71															
Dominant	32.45	37.47	19.94	7.92	13.29	- .24	9.18	16.81	3.25	15.88	20.31	8.91	4.47	10.25	1.86
Codominant	16.47	21.88	17.12	- 3.51	4.86	-5.22	1.31	8.23	-1.43	3.20	13.13	1.59	- 1.00	4.92	-1.21
Intermediate	18.89	10.09	9.66	- 9.80	1.72	.96	- 5.29	5.91	3.84	- 5.50	7.63	7.61	- 6.95	6.18	6.41
Suppressed	3.21	5.87	5.82	-14.88	-20.49	-4.69	-12.26	-12.27	-3.27	-10.83	- 9.74	- .66	-11.04	-10.24	1.51
24-tree average	17.76	18.83	13.13	- 5.07	- .16	-2.30	- 1.77	4.67	.60	.69	7.83	4.36	- 3.63	2.78	2.14

Table 5—Significance levels of the F tests in the analyses of variance of relative differences between volume growth by stem analysis and estimates by equation of volume growth and of differences in form factor for Boundary Creek

Factor	Bruce-DeMars	Turnbull-King	Curtis	Browne	Form factor
Thinning (T)	0.123	0.127	0.154	0.293	0.644
Crown class (CC)	.004	.005	.010	.046	.100
TXCC	.425	.672	.694	.574	.256
Years (Y)	.805	.923	.564	.580	.001
YXT	.780	.843	.880	.724	.025
YXCC	.091	.091	.101	.169	.422
YXTXCC	.101	.165	.238	.198	.347

Table 6—Average volume-equation discrepancy of growth, as percent of growth by volume equation by period, equation, and thinning treatment, Snow Creek[1]

Period	Volume growth by stem analysis[2]		Bruce-DeMars		Turnbull-King		Curtis		Browne	
	Thinned	Unthinned	Thinned	Unthinned	Thinned	Unthinned	Thinned	Unthinned	Thinned	Unthinned
	Cubic feet		*Percent*							
1951-60	9.27	9.34	-2.33	-4.32	-1.52	-2.87	-3.23	-4.67	-8.18	-9.28
	(2.64)	(2.17)	(6.10)	(6.87)	(5.82)	(7.42)	(5.87)	(7.36)	(5.59)	(6.81)
1961-72	16.65	13.91	2.98	.41	1.72	- .31	- 1.83	-5.73	- 3.61	-4.77
	(4.99)	(3.96)	(12.46)	(6.16)	(12.30)	(5.60)	(11.15)	(5.56)	(11.98)	(5.79)

[1] Standard deviations are in parentheses.
[2] Sample size: thinned, 10; unthinned, 6.

Crown class did have a significant effect on volume-growth discrepancies, but interactions of year x crown class and year x thinning x crown class were of marginal significance (table 5).

Average discrepancies were positive and considerably larger in the second than in the first period for dominant and codominant sample trees in lightly thinned plots (table 4). Average discrepancies were more nearly equal among periods for such sample trees in the control and heavily thinned plots. Because the interaction of period x thinning x crown class for volume-growth discrepancies is nonsignificant (table 5), this apparent difference could be merely a chance event in sampling.

Snow Creek

The limited data from Snow Creek show no significant difference for percentage deviations of volume growth of thinned plots compared with control. Average deviations in growth estimates by volume equations from those made by stem analysis for each treatment were less than 10 percent for all four volume equations (table 6).

Discussion

No comparison made at only two locations can prove a general lack of material error for any volume equation if applied over a range of stand conditions. For the Boundary Creek and Snow Creek areas, however, no serious discrepancies were found with any of the four volume equations examined. This assumes that growth estimates accurate to within about 10 percent are acceptable, providing that differences in errors between thinning treatments are not significant at the 0.10 level. For the two stands studied, standard volume equations provided satisfactory estimates of volume response to thinning.

Estimating volume and volume growth of individual trees is not the same as estimating these values for entire stands. Differences in stand estimates will be influenced by stand structure and the distribution of differences among size classes or crown classes. At Boundary Creek, the relative numbers of trees by crown classes were not significantly different among plots. Apparently for these data (table 4), averages of the three upper crown classes—which contribute most of the growth—will still be near or below 10 percent. Thus, these results can reasonably be extended to per-acre values at Boundary Creek.

The stem analysis work at Boundary Creek was originally undertaken in connection with analysis of a thinning study. Thinning is commonly expected to accelerate diameter growth of residual trees, accompanied by a redistribution of increment along the bole with consequent increased stem taper. I suspected that application of a standard volume equation during the response period might result in an overestimate of the volume response to thinning, but this study found no clear evidence of that. To the contrary, all four volume equations show substantial underestimation for dominant and codominant trees in the lightly thinned stands.

Practically, insufficient or biased sampling of trees measured for height and volume is probably a more serious source of error than any one of the volume equations in these mature young-growth stands.

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Similar estimates of tree and stand growth 19 years after thinning a 110-year-old stand of Douglas-fir were derived from stem analysis and standard volume-table, plot-compilation procedures.

Keywords: Volume tables, thinnings (-stand volume, stem analysis, Douglas-fir, *Pseudotsuga menziesii*.

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